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**A p.c.m. sound-in-syncs distribution system :
general description**

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A P.C.M. SOUND-IN-SYNCS DISTRIBUTION SYSTEM: GENERAL DESCRIPTION

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A P.C.M. SOUND-IN-SYNCS DISTRIBUTION SYSTEM: GENERAL DESCRIPTION

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A P.C.M. SOUND-IN-SYNCS DISTRIBUTION SYSTEM: GENERAL DESCRIPTION**SUMMARY**

This report, the first of a series, gives a general description of a system which has been developed for conveying a sound signal together with a vision signal along a vision link, the bandwidth required by the composite signal being no greater than that of the vision signal alone. The factors influencing the choice of system parameters are examined and the main features of the experimental equipment are described.

1. INTRODUCTION

The recent expansion of the BBC's services together with a shortage of high-quality music lines within the United Kingdom has made it desirable to develop alternative means for distributing sound signals from the originating studios to the transmitting stations. At the same time, the development of digital techniques has reached a point where pulse code modulation (p.c.m.) can be applied to the distribution of high-quality sound signals. During 1966 and 1967 Research Department carried out an investigation into the basic requirements of a high-quality p.c.m. sound distribution system,¹ into methods of achieving those requirements^{2,3} and into a method of inserting a p.c.m. sound signal into a television waveform.⁴ This latter investigation indicated that it would be feasible to convey the sound and vision components of a television programme as a composite signal using a single vision circuit, thus freeing the associated sound links for other uses; early experimental equipment operating on this principle, which has become known as 'sound-in-syncs', was demonstrated to representatives of the GPO in January 1968 and underwent a short field trial over the Broadcasting House - Crystal Palace circuit in March 1968. Further equipment incorporating a number of improvements was then built; this was subjected to a field trial over the London-to-Kirk O'Shotts circuit during the period August to October 1968 and was demonstrated to the press in November 1968. As a result of experience gained in the latter field trial, a number of modifications were made to the receiving terminal in order to render the sound signal immune to certain severe disturbances to which the composite signal or the input video signal may in practice be subjected.

Development of the sound-in-syncs system was completed by Research Department in March 1969: the present report, the first of a series, outlines the

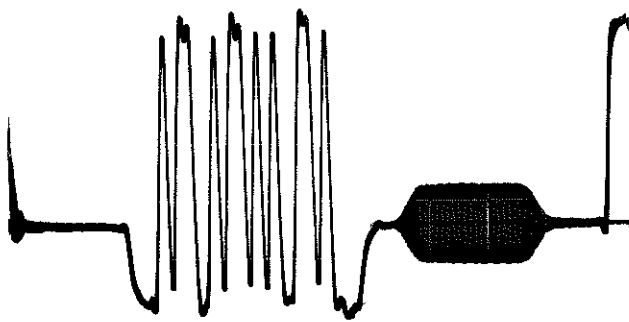
main features of the system; further reports will describe these features in greater detail.

2. CHOICE OF SIGNAL PARAMETERS

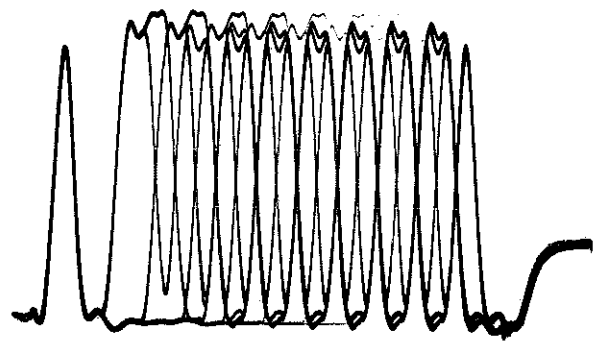
A previous report⁴ has given reasons for the choice of the line synchronising period for the inclusion of a high quality sound signal in the vision waveform. The system developed is intended to make the best possible use of the sync pulse time slot to meet the requirements of high-quality sound, while achieving maximum immunity to noise and distortion on the vision link, and minimum interference with the vision signal by the sound component. It was considered desirable too that present standards of performance of video sources and links should not need to be raised in order to ensure satisfactory operation of the sound-in-syncs system.

Many of the features included in the equipment demonstrated in January 1968 were retained. Two sound signal samples were carried by each line-synchronizing pulse, permitting an audio bandwidth of 14 kHz. The pulse code was made to express in binary notation the height of each sound signal sample measured from a reference level set just beyond the maximum negative signal excursion.

Binary p.c.m. was used so as to make the difference between possible values of the coded output as easily distinguishable as possible in the presence of noise and distortion. A ternary system would have required fewer digits and therefore allowed an increased digit spacing for a given number of quantizing levels, but this improvement would in the present circumstances have been more than counterbalanced by a reduction in the ability to discriminate correctly between pulse heights when noise and distortion were present.



(a) d.c. input applied to the equipment



(b) audio signal applied to the equipment

Fig. 1 - Photographs of sound-in-syncs waveform

5½ MHz 2T pulses extending from synchronizing level to peak white level were used to make up the sound pulse group, the 2T shape being employed because it gave a pulse of convenient duration whose energy was suitably contained within the video spectrum.⁵ In addition, of course, the response of the link to the 2T pulse is the subject of frequent examination, because it plays an important part in routine test procedures.

The arrangement of the two digital words within the synchronizing pulse was chosen so as to give minimum sound-to-picture crosstalk even in the presence of severe l.f. distortion on the link. The method used will be described in a later report on the combination and separation of sound and vision signals.⁶

The duration of the pulse group was restricted to 3.8 µs, commencing 400 ns after a point halfway down the leading edge of the line synchronizing pulse; it was thought that an earlier start would make sync separation at the receiving terminal difficult. Alternate equalizing pulses were widened by the insertion of the sound pulse group, but the waveform was restored to normal at the receiving terminal.

In the experimental equipment tested in March 1968, an 11-digit p.c.m. code was used; this gave a signal-to-noise ratio of 59 dB*, which was effectively raised to 63 dB by pre- and de-emphasis of the type recommended by the CCITT for carrier systems. The equipment was later modified to use a 10-digit code, giving a signal-to-noise ratio of 53 dB, but a frequency-dependent compander³ was introduced and an overall figure of 66 dB was thus achieved.

The use of a 10-digit code allowed the total number of pulses in the group to be reduced from a maximum of 23 to 21 (including a marker pulse always present at the start of the group and used for timing).

* peak signal/peak weighted noise, p.p.m. measurement.

The spacing between pulses was correspondingly increased, thus making the system less susceptible to noise and distortion.

Fig. 1(a) shows a photograph of the sound pulse group taken with a d.c. input to the system, while Fig. 1(b) shows the waveform observed when an audio signal is applied to the input.

3. PRINCIPAL DESIGN REQUIREMENTS

This section lists the principal requirements imposed on the design of the equipment by operational considerations, and briefly indicates what steps were taken to meet them. Further details will be found in the other reports in this series.^{6,8,9}

3.1. The Accommodation of Instabilities in the Pulse Train

Line synchronizing pulses are normally generated at 64 µs intervals, the line period being normally held constant to within 1 part in 10⁵. Disturbances to the regular sequence of sync pulses are caused when two video sources are being brought into synchronism, but the variations thus introduced are usually small. A large discontinuity occurs however when switching between two non-synchronous sources, and such events are common. It is desirable therefore that as much of the sound-in-syncs equipment as possible should be triggered from, rather than synchronized to, the incoming synchronizing pulses, so that its timing is immediately readjusted after such a disturbance. Certain of the circuits, for example those associated with synchronizing pulse reinsertion and expander gain control³ must of course have a 'memory' extending over many lines, and these circuits take some milliseconds to readjust after a non-sync switch. Most of the circuits however, were designed to be quiescent at the end of each cycle of operation and were thus 'hard-locked' to incoming synchronizing pulses. The

adoption of this technique led to equipment which was much more tolerant to disturbances of the synchronizing pulse train than was the prototype of January 1968.

Much greater disturbances than those mentioned above, however, can be caused by fault conditions. During the Kirk O'Shotts trial, interference originating at the video source or on the link and visible as flashing or complete break-up of picture also caused objectionable crackles to be superimposed on the output sound. A number of special circuits were therefore developed to detect the occurrence of disturbances of this type and to mute the sound output until conditions were restored to normal. These circuits, which included a sync-fail detector and a voltage over-swing detector, are described in the later reports on the combination and separation of sound and vision signals⁶ and on audio frequency companding.⁹

3.2. The Provision of Reserve Video Facilities

It was considered desirable that the sound continue to be available at the receiving terminal even if the vision signal failed at the input to the sending terminal. Provision was therefore made for a supply of standby synchronizing pulses to the sending terminal together with a means of automatically substituting them when the video input was removed.

3.3. The Optimization of Sound Pulse Detection

Sound pulse detection is carried out by examining the signal at a time during which the pulse is expected to be present, to see whether its instantaneous value is above or below a reference voltage. Maximum immunity to noise and distortion was ensured by arranging⁶ that this time and this reference voltage coincided with the centre of the 'eye'.⁴

3.4. The Accommodation of Sync Pulses of Non-Standard Level or Width

The equipment was designed so that the synchronizing level of the video signal leaving the receiving terminal was equal to that entering the sending terminal. The level at which the sound pulses were inserted was nevertheless made constant so that their detection would not be affected by changes in the incoming synchronizing level.

The output signal from the receiving terminal was arranged to have normal ($4.7 \mu\text{s}$) sync widths regardless of the input signal sync width.

3.5. The Avoidance of Crosstalk from Sound into Picture

If low-frequency distortion is present on the distribution link it is possible for variations in the mean d.c. level of the sound pulse group to disturb the level of back porch, particularly in the region just after the sync pulse. If the signal were then clamped in this region, these disturbances would be transferred to the whole of the active line, giving rise to an effect similar to 'sound-on-vision.'

To prevent this effect the configuration of the sound pulse group was chosen so as to minimize variations in mean level, the signal entering the receiving terminal was clamped as far away as possible from the sync pulse, and the complete waveform from beginning of pulse group to end of back porch (excluding the colour burst) was reconstituted. These processes are described in further detail in the report on the combination and separation of sound and video signals.⁶

4. THE EQUIPMENT

The equipment was built as six separate units whose functions are indicated in the block diagram given in Fig. 2.

The timing of most operations was determined by twice-line pulses derived from the video signals by means of sync separators included at the sending and receiving terminals.

The sound signal entered the compressor, which was in fact a quick acting audio-frequency limiter of the type required in any case for overload protection. The signal was however first pre-emphasized, after which a pilot tone at line frequency was added to it. After compression the signal entered the analogue-to-digital converter (a.d.c.);⁸ here it was sampled at twice-line rate, each sample being converted to a 10-digit binary word.

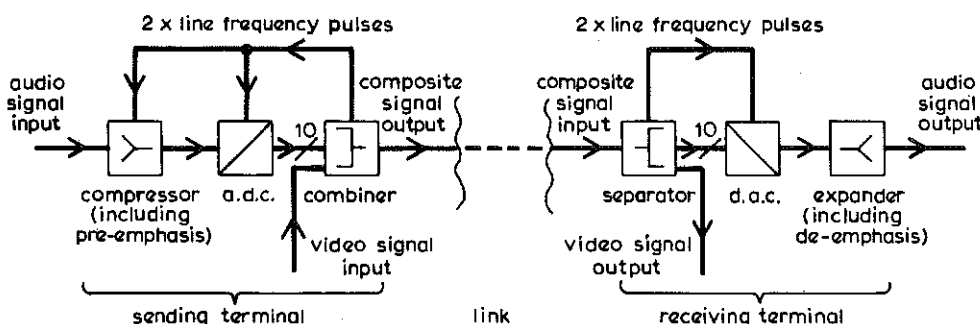


Fig. 2 - Block diagram of sound-in-syncs equipment

The two digital words generated during a given line period were passed to the combiner, where they were formed up in the required order, shaped by a 2T pulse filter, and then gated into the video waveform (see Fig. 1).

On arrival of the composite sound-in-syncs signal at the receiving terminal, the opposite processes occurred. In the separator (Fig. 2) a two-way switch routed the two digital words into a register, from which they were delivered to the digital-to-analogue converter (d.a.c.) at half-line intervals, and the video component that remained into a circuit in which a new sync bottom, trailing edge, and back porch were generated and inserted.

The analogue signal from the d.a.c. passed to the expander, the gain of which was controlled by the amplitude of the pilot tone. The output audio signal was then recovered by de-emphasis.

Fig. 3 shows the sending and receiving terminals; each terminal used about 150 integrated circuits to perform the digital operations, together with discrete components for the analogue circuitry. Special test facilities, including a digital sawtooth generator and a pilot tone test generator, were provided; these are described in the other reports in this series.

5. PERFORMANCE

The experimental sound-in-syncs equipment was subjected to a number of tests in the laboratory and under service conditions. The results of these tests have already been published;^{10,11,12} the purpose of this section is to give additional information and to

present a summary of the performance of the equipment which is complete up until the conclusion of Research Department's work on the project. More detailed information on individual units is given in the other reports in this series.^{6,8,9}

5.1. The Audio Circuit

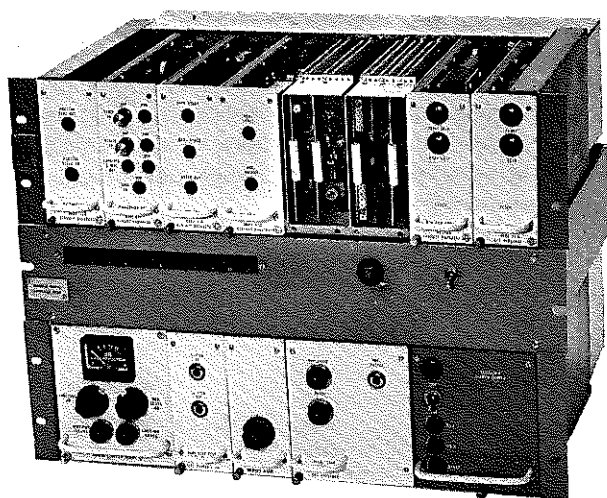
The overall response/frequency characteristic of the equipment, as measured with input levels of 0dBm and -10dBm, is given in Fig. 4. The slight difference in the shape of the curves is due to minor gain tracking errors in the compandor. This data is in close agreement with test results previously published.¹⁰

During measurements of the response/frequency characteristic, the presence of low-level beats between the input frequency or its harmonics and the sampling frequency were observed. These components were too small to affect the measurement and they did not have any perceptible effect on normal programme. Improvements to the analogue circuitry are expected to reduce their magnitudes significantly as well as improving the overall distortion figures.

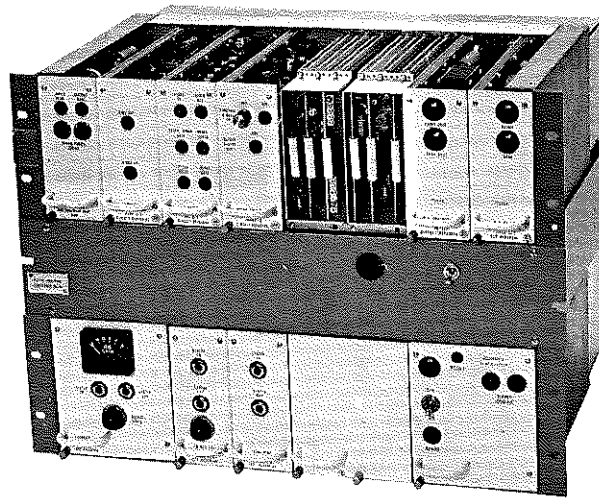
When a 1kHz tone of maximum permitted level was injected at the sending terminal, distortion components of the following amplitudes were observed at the output of the receiving terminal: second harmonic 0.48%, third harmonic 0.08%, fourth harmonic 0.00%.

As mentioned in Section 2, the audio signal-to-noise ratio was 66dB (p.p.m. measurement - peak signal/peak weighted noise).

It should be emphasized that the above characteristics are independent of the nature of the link unless



(a)



(b)

Fig. 3 - Photographs of experimental equipment

(a) sending terminal

(b) receiving terminal

this is so poor as to prevent the digital signal from being correctly decoded.

5.2. The Video Circuit

The main characteristics of the vision circuits in the sound-in-syncs equipment have been described in an earlier report¹⁰ and are summarized below:

2T pulse/bar ratio	100%
2T K rating	<1/2%
25 μ s bar K rating	<1/2%
Non-linearity	1%
Differential gain	5%
Differential phase	2.7°

Improved circuits have since been developed by means of which the last two figures could be significantly reduced.

Since the publication of the above report it was found that small echoes of delay sufficient to superimpose a delayed version of the sound pulse group on to the end of the back porch (the position at which clamping takes place in the receiving terminal) gave rise to 'sound-on-vision.' The effect was not considered serious since reflections having that delay (about 5 μ s) are rare on the distribution network. Experiments showed, however, that it could be reduced by a modification to the clamp circuit.

5.3. Susceptibility to Interference and Distortion

The susceptibility of the experimental equipment to random noise was tested by adding noise to the composite sound-in-syncs signal. The sound signal obtained from the receiving terminal was unaffected as long as the peak video signal-to-r.m.s. unweighted noise ratio was greater than 27 dB. This figure still applied when the maximum distortions permitted on 2 U.K. reference links in tandem were added. A generous measure of protection such as this is desirable because the onset of failure to detect the sound pulse group correctly is sudden and its effect on the sound output catastrophic.

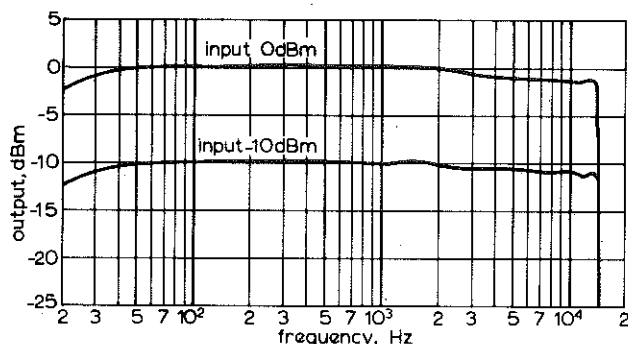


Fig. 4 - Audio response/frequency characteristic of experimental equipment

The circuits included for detection of disturbances to the composite signal or to the video signal at the input to the sending terminal were able to suppress most of the corresponding disturbances to the sound signal.¹² These circuits usually actuated the mute unnecessarily when the video input signal was switched between non-synchronous sources, but the short break thus introduced into the sound output was imperceptible.

6. CONCLUSIONS

The experimental equipment described in the report has demonstrated that a high quality sound-in-syncs system having the parameters outlined is technically feasible and can be satisfactorily introduced into the present vision distribution network.

7. ACKNOWLEDGEMENTS

Tests on the experimental sound-in-syncs equipment were carried out in collaboration with Communications and Designs Department staff, whose co-operation is gratefully acknowledged.

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